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XX. *On new compounds of carbon and hydrogen, and on certain other products obtained during the decomposition of oil by heat.*
By M. FARADAY, F. R. S. Cor. Mem. Royal Academy of Sciences of Paris, &c.

Read June 16, 1825.

THE object of the paper which I have the honour of submitting at this time to the attention of the Royal Society, is to describe particularly two new compounds of carbon and hydrogen, and generally, other products obtained during the decomposition of oil by heat. My attention was first called to the substances formed in oil at moderate and at high temperatures, in the year 1820 ; and since then I have endeavoured to lay hold of every opportunity for obtaining information on the subject. A particularly favourable one has been afforded me lately through the kindness of Mr. GORDON, who has furnished me with considerable quantities of a fluid obtained during the compression of oil gas, of which I had some years since possessed small portions, sufficient to excite great interest, but not to satisfy it.

It is now generally known, that in the operations of the Portable Gas Company, when the oil gas used is compressed in the vessels, a fluid is deposited, which may be drawn off and preserved in the liquid state. The pressure applied amounts to 30 atmospheres ; and in the operation, the gas previously contained in a gasometer over water, first passes into a large strong receiver, and from it, by pipes, into the

portable vessels. It is in the receiver that the condensation principally takes place; and it is from that vessel that the liquid I have worked with has been taken. The fluid is drawn off at the bottom by opening a conical valve: at first a portion of water generally comes out, and then the liquid. It effervesces as it issues forth; and by the difference of refractive power it may be seen, that a dense transparent vapour is descending through the air from the aperture. The effervescence immediately ceases; and the liquid may be readily retained in ordinary stoppered, or even corked bottles; a thin phial being sufficiently strong to confine it. I understand that 1000 cubical feet of good gas yield nearly one gallon of the fluid.

The substance appears as a thin light fluid; sometimes transparent and colourless, at others opalescent, being yellow or brown by transmitted, and green by reflected light. It has the odour of oil gas. When the bottle containing it is opened, evaporation takes place from the surface of the liquid; and it may be seen by the striæ in the air that vapour is passing off from it. Sometimes in such circumstances it will boil, if the bottle and its contents have had their temperature raised a few degrees. After a short time this abundant evolution of vapour ceases, and the remaining portion is comparatively fixed.

The specific gravity of this substance is 0.821. It does not solidify at a temperature of 0° F. It is insoluble, or nearly so, in water; very soluble in alcohol, ether, and volatile and fixed oils. It is neutral to test colours. It is not more soluble in alkaline solutions than in water; and only a small portion is acted upon by them. Muriatic acid has no

action upon it. Nitric acid gradually acts upon it, producing nitrous acid, nitric oxide gas, carbonic, and sometimes hydrocyanic acid, &c. but the action is not violent. Sulphuric acid acts upon it in a very remarkable and peculiar manner, which I shall have occasion to refer to more particularly presently.

This fluid is a mixture of various bodies ; which, though they resemble each other in being highly combustible, and throwing off much smoke when burnt in large flame, may yet by their difference of volatility be separated in part from each other. Some of it drawn from the condenser, after the pressure had been repeatedly raised to 30 atmospheres, and at a time when it was at 28 atmospheres, then introduced rapidly into a stoppered bottle and closed up, was, when brought home, put into a flask and distilled, its temperature being raised by the hand. The vapour which came off, and which caused the appearance of boiling, was passed through a glass tube at 0° , and then conducted to the mercurial trough ; but little uncondensed vapour came over, not more than thrice the bulk of the liquid ; a portion of fluid collected in the cold tube, which boiled and evaporated when the temperature was allowed to rise ; and the great bulk of the liquid which remained, might now be raised to a comparatively high point, before it entered into ebullition.

A thermometer being introduced into another portion of the fluid, heat was applied, so as to keep the temperature just at the boiling point. When the vessel containing it was opened, it began to boil at 60° F. As the more volatile portions were dissipated, the temperature rose : before a tenth part had been thrown off, the temperature was above 100° .

The heat continued gradually to rise, and before the substance was all volatilized, it had attained 250°.

With the hope of separating some distinct substances from this evident mixture, a quantity of it was distilled, and the vapours condensed at a temperature of 0° into separate portions, the receiver being changed with each rise of 10° in the retort, and the liquid retained in a state of incipient ebullition. In this way a succession of products were obtained ; but they were by no means constant ; for the portions, for instance, which came over when the fluid was boiling from 160° to 170°, when redistilled, began to boil at 130°, and a part remained which did not rise under 200°. By repeatedly rectifying all these portions, and adding similar products together, I was able to diminish these differences of temperature, and at last bring them more nearly to resemble a series of substances of different volatility. During these operations I had occasion to remark, that the boiling point was more constant at, or between 176° and 190°, than at any other temperature ; large quantities of fluid distilling over without any change in the degree ; whilst in other parts of the series it was constantly rising. This induced me to search in the products obtained between these points for some definite substance, and I ultimately succeeded in separating a new compound of carbon and hydrogen, which I may by anticipation distinguish as bi-carburet of hydrogen,

Bi-carburet of hydrogen.

This substance was obtained in the first instance in the following manner : tubes containing portions of the above rectified products were introduced into a freezing mixture at

° ; many of them became turbid, probably from the presence of water ; one, received at 176°, (by which is meant that that was the boiling point of the contents of the retort when it came over) became partly solid, crystals forming round the side, and a fluid remaining in the centre ; whilst two other portions, one received at 186°, and the other at 190°, became quite hard. A cold glass rod being introduced into one of these tubes, the mass within was found to resist considerable pressure ; but by breaking it down, a solid part was thrust to the bottom of the tube, whilst a fluid remained above : the fluid was poured off, and in this way the solid portion partly purified. The contents of the tube were then allowed to fuse, were introduced into a larger and stronger tube, furnished with another which entered loosely within it, both being closed of course at the lower end ; then again lowering the temperature of the whole to 0°, bibulous paper was introduced, and pressed on to the surface of the solid substance in the large tube by the end of the smaller one. In this way much fluid was removed by successive portions of paper, and a solid substance remained, which did not become fluid until raised to 28° or 29°. To complete the separation of the permanently fluid part, the substance was allowed to melt, then cast into a cake in a tin foil mould, and pressed between many folds of bibulous paper in a BRAMAH's press, care having been taken to cool the paper, tin foil, flannel, boards, and other things used, as near to 0° as possible, to prevent solution of the solid substance in the fluid part to be removed. It was ultimately distilled from off caustic lime, to separate any water it might contain.

The general process, which appears to me to be the best

for the preparation of this substance only, is to distil a portion of the fluid deposited during the condensation of oil gas, to set aside the product obtained before the temperature rises to 170° , to collect that which comes over by 180° , again separately that which comes over by 190° , and also the portion up to 200° or 210° . That before 170° will upon redistillation yield portions to be added to those of 180° and 190° ; and the part obtained from 190° upwards will also, when redistilled, yield quantities boiling over at 180° , 190° , &c. Having then these three portions obtained at 180° , 190° , and 200° , let them be rectified one after the other, and the products between 175° and 195° received in three or four parts at successive temperatures. Then proceed with these as before described.

It will sometimes happen, when the proportion of bi-carburet of hydrogen is small in the liquid, that the rectifications must be many times repeated before the fluids at 185° and 190° will deposit crystals on cooling; that is to say, before sufficient of the permanently fluid part at low temperatures has been removed, to leave a solution so saturated as to crystallize at 0° .

Bi-carburet of hydrogen appears in common circumstances as a colourless transparent liquid, having an odour resembling that of oil gas, and partaking also of that of almonds. Its specific gravity is nearly 0.85 at 60° . When cooled to about 32° it crystallizes, becoming solid; and the portions which are on the sides of the glass exhibit dendritical forms. By having tubes containing thin solid films of it in ice-cold water, and allowing the temperature to rise slowly, its fusing point was found to be very nearly 42° F.; but when

liquid it may, like water and some saline solutions, be cooled much below that point before any part becomes solid. It contracts very much on congealing, 9 parts in bulk becoming 8 very nearly ; hence its specific gravity in that state is about 0.956. At 0° it appears as a white or transparent substance, brittle, pulverulent, and of the hardness nearly of loaf sugar.

It evaporates entirely when exposed to the air. Its boiling point in contact with glass is 186°. The specific gravity of its vapour, corrected to a temperature of 60°, is nearly 40 Hydrogen being 1; for 2.3 grains became 3.52 cubic inches of vapour at 212°. Barometer 29.98. Other experiments gave a mean approaching very closely to this result.

It does not conduct electricity.

This substance is very slightly soluble in water; very soluble in fixed and volatile oils, in ether, alcohol, &c.; the alcoholic solution being precipitated by water. It burns with a bright flame and much smoke. When admitted to oxygen gas, so much vapour rises as to make a powerfully detonating mixture. When passed through a red hot tube it gradually deposits carbon, yielding carburetted hydrogen gas.

Chlorine introduced to the substance in a retort exerted but little action until placed in sun-light, when dense fumes were formed, without the evolution of much heat; and ultimately much muriatic acid was produced, and two other substances, one a solid crystalline body, the other a dense thick fluid. It was found by further examination, that neither of these were soluble in water; that both were soluble in alcohol—the liquid readily, the solid with more difficulty. Both of them appeared to be triple compounds of chlorine,

carbon, and hydrogen ; but I reserve the consideration of these, and of other similar compounds, to another opportunity.

Iodine appears to exert no action upon the substance in several days in sun-light ; it dissolves in the liquid in small quantity, forming a crimson solution.

Potassium heated in the liquid did not lose its brilliancy, or exert any action upon it, at a temperature of 186° .

Solution of alkalis, or their carbonates, had no action upon it.

Nitric acid acted slowly upon the substance and became red, the fluid remaining colourless. When cooled to 32° , the substance became solid and of a fine red colour, which disappeared upon fusion. The odour of the substance with the acid was exceedingly like that of almonds, and it is probable that hydrocyanic acid was formed. When washed with water, it appeared to have undergone little or no change.

Sulphuric acid added to it over mercury exerted a moderate action upon it, little or no heat was evolved, no blackening took place, no sulphurous acid was formed ; but the acid became of a light yellow colour, and a portion of a clear colourless fluid floated, which appeared to be a product of the action. When separated, it was found to be bright and clear, not affected by water or more sulphuric acid, solidifying at about 34° , and being then white, crystalline, and dendritical. The substance was lighter than water, soluble in alcohol, the solution being precipitated by a small quantity of water, but becoming clear by great excess.*

* The action of sulphuric acid on this and the other compounds to be described, is very remarkable. It is frequently accompanied with heat ; and large quantities of

With regard to the composition of this substance, my experiments tend to prove it a binary compound of carbon and hydrogen, two proportionals of the former element being united to one of the latter. The absence of oxygen is proved by the inaction of potassium, and the results obtained when passed through a red hot tube.

The following is a result obtained when it was passed in vapour over heated oxide of copper. 0.776 grains of the substance produced 5.6 cubic inches of carbonic acid gas, at a temperature of 60° , and pressure 29.98 inches; and 0.58 grains of water were collected. The 5.6 cubic inches of gas are equivalent to 0.711704 grains of carbon by calculation, and the 0.58 grains of water to 0.064444 of hydrogen.

Carbon . . 0.711704 or 11.44

Hydrogen . . 0.064444 or 1.

These quantities nearly equal in weight the weight of the substance used; and making the hydrogen 1, the carbon is not far removed from 12, or two proportionals.

those bodies which have elasticity enough to exist as vapours when alone at common pressures, are absorbed. No sulphurous acid is produced; nor when the acid is diluted, does any separation of the gas, vapour or substance take place, except of a small portion of a peculiar product resulting from the action of the acid on the substances, and dissolved by it. The acid combines directly with carbon and hydrogen; and I find when united with bases forms a peculiar class of salts, somewhat resembling the sulphovinates, but still different from them. I find also that sulphuric acid will condense and combine with olefiant gas, no carbon being separated, or sulphurous or carbonic acid being formed; and this absorption has in the course of 18 days amounted to 84.7 volumes of olefiant gas to 1 volume of sulphuric acid. The acid produced combines with bases, &c. forming peculiar salts, which I have not yet had time, but which it is my intention, to examine, as well as the products formed by the action of sulphuric acid on naphtha, essential oils, &c. and even upon starch and lignine, in the production of sugar, gum, &c. where no carbonization takes place, but where similar results seem to occur.

Four other experiments gave results all approximating to the above. The mean result was 1 hydrogen, 11.576 carbon.

Now considering that the substance must, according to the manner in which it was prepared, still retain a portion of the body boiling at 186°, but remaining fluid at 0°, and which substance I find, as will be seen hereafter, to contain less carbon than the crystalline compound, (only about 8.25 to 1 of hydrogen,) it may be admitted, I think, that the constant though small deficit of carbon found in the experiments is due to the portion so retained; and that the crystalline compound would, if pure, yield 12 of carbon for each 1 of hydrogen; or two proportionals of the former element and one of the latter.

2 proportionals carbon . 12 }
1 hydrogen 1 } 13 bi-carburet of hydrogen.

This result is confirmed by such data as I have been able to obtain by detonating the vapour of the substance with oxygen. Thus in one experiment 1092 mercury grain measures of oxygen at 62° had such quantity of the substance introduced into it as would entirely rise in vapour; the volume increased to 8505, hence the vapour amounted to 413 parts, or $\frac{1}{20.6}$ of the mixture nearly. Seven volumes of this mixture were detonated in an eudiometer tube by an electric spark, and diminished in consequence nearly to 6.1: these acted upon by potash were further diminished to 4, which were pure oxygen. Hence 3 volumes of mixture had been detonated, of which nearly 0.34 was vapour of the substance, and 2.65 oxygen. The carbonic acid amounted to 2.1 volumes, and must have consumed an equal bulk of oxygen gas; so that 0.55 remain as the quantity of oxygen which

has combined with the hydrogen to form water, and which with the 0.34 of vapour nearly make the diminution of 0.9.

It will be seen at once that the oxygen required for the carbon is four times that for the hydrogen; and that the whole statement is but little different from the following theoretical one, deduced partly from the former experiments. 1 volume of vapour requires 7.5 volumes of oxygen for its combustion; 6 of the latter combine with carbon to form 6 of carbonic acid, and the 1.5 remaining combine with hydrogen to form water. The hydrogen present therefore in this compound is equivalent to 3 volumes, though condensed into one volume in union with the carbon; and of the latter elements there are present six proportionals, or 36 by weight. A volume therefore of the substance in vapour contains

$$\begin{array}{rcl}
 \text{Carbon} & - & 6 \times 6 = 36 \\
 \text{Hydrogen} & - & 1 \times 3 = 3 \\
 & & \hline \\
 & & 39
 \end{array}$$

and its weight or specific gravity will be 39, hydrogen being 1. Other experiments of ~~eq~~ same kind gave results according with these.

Among the liquid products obtained from the original fluid was one which, procured as before mentioned, by submitting to 0° the portion distilling over at 180° or 190°, corresponded with the substance already described, as to boiling points, but differed from it in remaining fluid at low temperatures; and I was desirous of comparing the two together. I had no means of separating this body from the

bi-carburet of hydrogen, of which it would of course be a saturated solution at 0° . Its boiling point was very constantly 186° . In its general characters of solubility, combustibility, action of potassium, &c. it agreed with the substance already described. Its specific gravity was 0.86 at 60° . When raised in vapour 1.11 grain of it gave 1.573 cubic inches of vapour at 212° , equal to 1.212 cubic inches at 60° . Hence 100 cubic inches would weigh about 91.6 grains, and its specific gravity would be 43.25 nearly. In another experiment, 1.72 grains gave 2.4 cubic inches at 212° , equal to 1.849 cubic inches at 60° ; from which the weight of 100 cubic inches would be deduced as 93 grains; and its specific gravity to hydrogen as 44 to 1. Hence probably the reason why, experimentally, the specific gravity of bi-carburet of hydrogen in vapour was found higher, than by theory it would appear to be when pure.

Sulphuric acid acted much more powerfully upon this substance than upon the bi-carburet: great heat was evolved, much discolouration occasioned, and a separation took place into a thick black acid, and a yellow lighter liquid, resisting any further action at common temperatures.

0.64 grains of this substance were passed over heated oxide of copper; 4.51 cubic inches of carbonic acid gas were obtained, and 0.6 grains of water. The carbonic acid and water are equivalent to

Carbon	-	0.573176, or 8.764
Hydrogen	-	0.066666 1.

but as the substance must have contained much bi-carburet of hydrogen, it is evident that, if in a pure state, the carbon would fall far short of the above quantity, and the compound

would approximate of course to a simple carburet of hydrogen containing single proportionals.

New carburet of hydrogen.

Of the various other products from the condensed liquor, the next most definite to the bi-carburet of hydrogen appears to be that which is most volatile. If a portion of the original liquid be warmed by the hand, or otherwise, and the vapour which passes off be passed through a tube at 0° , very little uncondensed vapour will go on to the mercurial trough ; but there will be found after a time a portion of fluid in the tube, distinguished by the following properties. Though a liquid at 0° , it upon slight elevation of temperature begins to boil, and before it has attained 32° , is all resolved into vapour or gas, which may be received and preserved over mercury.

This gas is very combustible, and burns with a brilliant flame. The specific gravity of the portion I obtained was between 27 and 28, hydrogen being 1 : for 39 cubic inches introduced into an exhausted glass globe were found to increase its weight 22.4 grains at 60° F. bar. 29.94. Hence 100 cubic inches weigh nearly 57.44 grains.

When cooled to 0° it condensed again, and inclosed in this state in a tube of known capacity, and hermetically sealed up, the bulk of a given weight of the substance at common temperatures was ascertained. This compared with water gave the specific gravity of the liquid as 0.627 at 54° . It is therefore among solids or liquids the lightest body known.

This gas or vapour when agitated with water is absorbed in small quantities. Alcohol dissolves it in large quantity ; and a solution is obtained, which, upon the addition of water,

effervesces, and a considerable quantity of the gas is liberated. The alcoholic solution has a peculiar taste, and is neutral to test papers.

Olive oil dissolves about six volumes of the gas.

Solution of alkali does not affect it; nor does muriatic acid.

Sulphuric acid condenses the gas in very large quantity; 1 volume of the acid condensing above 100 volumes of the vapour. Sometimes the condensation is perfect, at other times a small quantity of residual gas is left, which burns with a pale blue flame, and seems to be a product of too rapid action. Great heat is produced during the action; no sulphurous acid is formed; the acid is much blackened, has a peculiar odour, and upon dilution generally becomes turbid, but no gas is evolved. A permanent compound of the acid with carbon and hydrogen is produced, and enters as before mentioned into combination with bases.

A mixture of 2 volumes of this vapour with 14 volumes of pure oxygen was made, and a portion detonated in an eudiometer tube. 8.8 volumes of the mixture diminished by the spark to 5.7 volumes, and these by solution of potash to 1.4 volumes, which were oxygen. Hence 7.4 volumes had been consumed, consisting of

Vapour of substance	-	-	1.1
Oxygen	-	-	6.3
Carbonic acid formed	-	-	4.3
Oxygen in carbonic acid	-	-	4.3
Oxygen combining with hydrogen	-	-	2.0
Diminution by spark	-	-	3.1

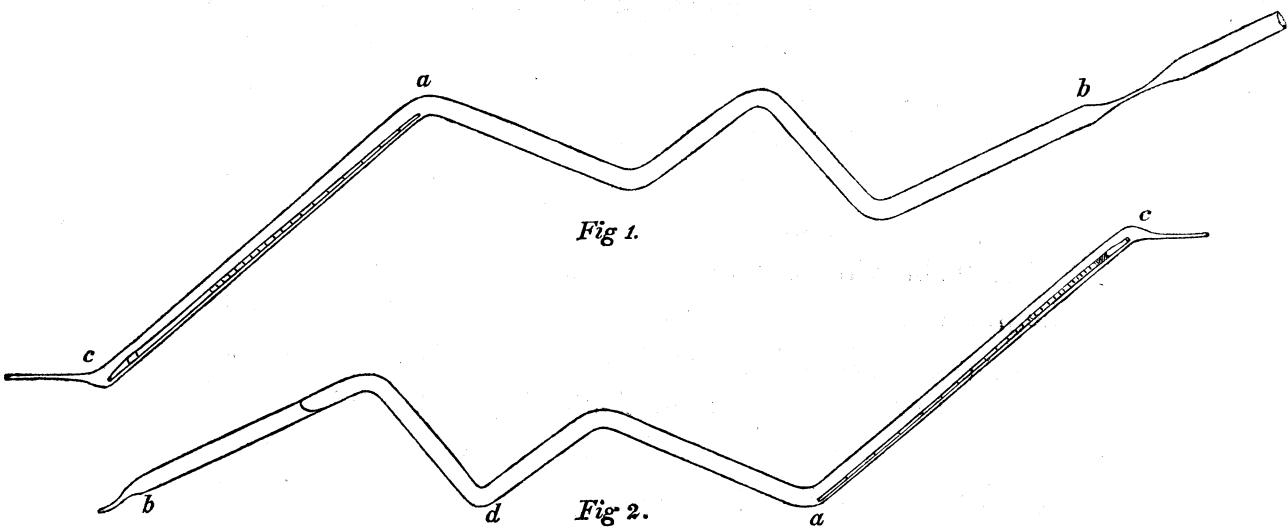
This is nearly as if 1 volume of the vapour or gas had required 6 volumes of oxygen, had consumed 4 of them in

producing 4 of carbonic acid gas, and had occupied the other 2 by 4 of hydrogen to form water. Upon which view, 4 volumes or proportionals of hydrogen = 4, are combined with 4 proportionals of carbon = 24, to form one volume of the vapour, the specific gravity of which would therefore be 28. Now this is but little removed from the actual specific gravity obtained by the preceding experiments; and knowing that this vapour must contain small portions of other substances in solution, there appears no reason to doubt that, if obtained pure, it would be found thus constituted.

As the proportions of the elements in this vapour appear to be the same as in olefiant gas, it became interesting to ascertain whether chlorine had the same action upon it as on the latter body. Chlorine and the vapour were therefore mixed in an exhausted retort: rapid combination took place, much heat was evolved, and a liquor produced resembling hydro-chloride of carbon, or the substance obtained by the same process from olefiant gas. It was transparent, colourless, and heavier than water. It had the same sweet taste, but accompanied by an after aromatic bitterness, very persistent. Further, it was composed of nearly equal volumes of the vapour and chlorine: it could not therefore be the same as the hydro-chloride of carbon from olefiant gas, since it contained twice as much carbon and hydrogen. It was therefore treated with excess of chlorine in sun-light: action slowly took place, more chlorine combined with the substance, muriatic acid was formed, and ultimately a fluid tenacious triple compound of chlorine, carbon, and hydrogen was obtained; but no chloride of carbon. This is a remarkable circumstance, and assists in showing, that though the

elements are the same, and in the same proportions as in olefiant gas, they are in a very different state of combination.

The tension of the most volatile part of the condensed oil gas liquid, and indeed of the substance next beneath olefiant gas in elasticity existing in the mixture constituting oil gas, appears to be equal to about 4 atmospheres at the temperature of 60° . To ascertain this a tube was prepared, like the one delineated in the sketch, Fig. 1, containing a mercurial



gauge at *a*, *c*, and the extremities being open. It was then cooled to 0° from *a* to *b*, and in that state made the receiver into which the first product from a portion of the original fluid was distilled. The part at *b* was then closed by a spirit lamp; and having raised enough vapour to make it issue at

Note. The particular inclination of the parts of the tube one to another was given, that the fluid when required might be returned from *a* to *d* without passing on to *b*.

c, that was also closed. The instrument now placed as at Fig. 2, had *a* and *d* cooled to 0° , whilst the fluid collected in *b* was warmed by the hand or the air; and when a portion had collected in *d* sufficient for the purpose, the whole instrument was immersed in water at 60° ; and before the vapour had returned and been all dissolved by the liquid at *b*, the pressure upon the gauge within was noted. Sometimes the fluid at *d* was rectified by warming that part of the tube, and cooling *a* only, the reabsorption at *b* being prevented or rather retarded, in consequence of the superior levity of the fluid at *d*, so that the first portions which returned to *b* lay upon it in a stratum, and prevented sudden solution in the mass below. This difference in specific gravity was easily seen upon agitation, in consequence of the striæ produced during the mixture.

Proceeding in this way it was found, as before stated, that the highest elastic power that could be obtained from the substances in the tube, was about 4 atmospheres at 60° ; and as there seems no reason to doubt, but that portions of the most volatile substances in oil gas beneath olefiant gas were contained in the fluid, inasmuch as even olefiant gas itself is dissolved by it in small proportions, it may be presumed that there is no substance in oil gas much more volatile than the one requiring a pressure of 4 atmospheres at 60° , except the well known compounds; or, in other words, that there is not a series of substances passing upwards from this body to olefiant gas, and possessing every intermediate degree of elasticity, as there seems to be from this body downwards, to compounds requiring 250° or 300° for their ebullition.

In reference to these more volatile products, I may state

that I have frequently observed a substance come over in small quantity, rising with the vapour which boils off at 50° or 60° , and crystallizing in spiculæ in the receiver at 0° . A temperature of 8° or 10° causes its fusion and disappearance. It is doubtless a peculiar and definite body, but the quantity is extremely small, or else it is very soluble in the accompanying fluids. I have not yet been able to separate it, or examine it minutely.

I ventured some time since upon the condensation of various gases,* to suggest the possibility of forming a vapour lamp, which containing a brilliantly combustible substance, liquid at a pressure of two, three, or four atmospheres at common temperatures, but a vapour at less pressure, should furnish a constant light for a length of time, without requiring high, or involving inconstant, pressure. Such a lamp I have now formed, feeding it with the substance just described ; and though at present it is only a matter of curiosity, and perhaps may continue so, yet there is a possibility that processes may be devised, by which the substance may be formed in larger quantity, and render an application of this kind practically useful.

On the remaining portions of the condensed oil gas liquor.

It has been before mentioned, that by repeated distillations various products were obtained, boiling within limits of temperature which did not vary much ; and which when distilled were not resolved into other portions, differing far from each other in volatility, as always happened in the earlier distillations. Though conscious that there were mixtures, perhaps

* Quarterly Journal of Science, XVI. 240.

of unknown bodies, and certainly in unknown proportions ; yet experiments were made on their composition by passing them over oxide of copper, in hopes of results which might assist in suggesting correct views of their nature. They all appeared to be binary compounds of carbon and hydrogen, and the following table exhibits the proportions obtained : the first column expressing the boiling temperature at which the products were distilled, as before mentioned ; the second the hydrogen, made a constant quantity ; and the third the carbon.

140°	-	1	-	7.58
150°	-	1	-	8.38
160°	-	1	-	7.90
176°	-	1	-	8.25
190°	-	1	-	8.76
200°	-	1	-	9.17
210°	-	1	-	8.91
220°	-	1	-	8.46

These substances generally possess the properties before described, as belonging to the bi-carburet of hydrogen. They all resist the action of alkali, even that which requires a temperature above 250° for its ebullition ; and in that point are strongly distinguished from the oils from which they are produced. Sulphuric acid acts upon them instantly with phenomena already briefly referred to.

Dr. HENRY, whilst detailing the results of his numerous and exact experiments in papers laid before the Royal Society, mentions in that read February 22, 1821,* the discovery

* *Philosophical Transactions.*

made by Mr. DALTON, of a vapour in oil gas of greater specific gravity than olefiant gas, requiring much more oxygen for its combustion, but yet condensable by chlorine. Mr. DALTON appears to consider all that was condensable by chlorine as a new and constant compound of carbon and hydrogen ; but Dr. HENRY, who had observed that the proportion of oxygen required for its combustion varied from 4,5 to 5 volumes, and the quantity of carbonic acid produced, from 2,5 to 3 volumes, was inclined to consider it as a mixture of the vapour of a highly volatile oil with the olefiant and other combustible gases ; and he further mentions, that naphtha in contact with hydrogen gas will send up such a vapour ; and that he has been informed, that when oil gas was condensed in GORDON's lamp, it deposited a portion of highly volatile oil.

A writer in the Annals of Philosophy, N. S. III. 37, has deduced from Dr. HENRY's experiments, that the substance, the existence of which was pointed out by Mr. DALTON, was not a new gas *sui generis*, " but a modification of olefiant gas, constituted of the same elements as that fluid, and in the same proportions, with this only difference, that the compound atoms are triple instead of double :" and Dr. THOMSON has adopted this opinion in his Principles of Chemistry. This, I believe, is the first time that two gaseous compounds have been supposed to exist, differing from each each other in nothing but density ; and though the proportion of 3 to 2 is not confirmed, yet the more important part of the statement is, by the existence of the compound described at page 452, which though composed of carbon and

hydrogen in the same proportion as in olefiant gas, is of double the density.*

It is evident, that the vapour observed by Mr. DALTON and Dr. HENRY must have contained not only this compound, and a portion of the bi-carburet of hydrogen, but also portions of the other, as yet apparently indefinite substances ; and there can be no doubt that the quantity of these vapours will vary from the point of full saturation of the gas, when

* In reference to the existence of bodies composed of the same elements and in the same proportions, but differing in their qualities, it may be observed, that now we are taught to look for them, they will probably multiply upon us. I had occasion formerly to describe a compound of olefiant gas and iodine (*Phil. Trans.* CXI. 72), which upon analysis yielded one proportional of iodine, two proportionals of carbon, and two of hydrogen, (*Quarterly Journal*, XIII. 429). M. SERRULAS, by the action of potassium upon an alcoholic solution of iodine, obtained a compound decidedly different from the preceding in its properties ; yet when analysed, it yielded the same elements in the same proportions, (*Ann. de Chimie*, XX. 245, XXII. 172).

Again. MM. LIEBIG and GAY LUSSAC, after an elaborate and beautiful investigation of the nature of fulminating compounds of silver, mercury, &c. were led to the conclusion that they were salts, containing a new acid, and owed their explosive powers to the facility with which the elements of this acid separated from each other. (*Annales de Chimie*, XXIV. 294, XXV. 285). The acid itself being composed of one proportional of oxygen, one of nitrogen, and two of carbon, is equivalent to a proportional of oxygen + a proportional of cyanogen, and is therefore considered as a true cyanic acid. But M. WOHLER, by deflagrating together a mixture of ferro-prussiate of potash and nitre, has formed a salt, which, according to his analysis, is a true cyanate of potash. The acid consists of one proportion of oxygen, one of nitrogen, and two of carbon. It may be transferred to various other bases, as the earths, the oxides of lead, silver, &c.; but the salts formed have nothing in common with the similar salts of MM. LIEBIG and GAY LUSSAC, except their composition, (*GILBERT's Annalen*, LXXIII. 157. *Ann. de Chimie*, XXVII. 190). M. GAY LUSSAC observes, that if the analysis be correct, the difference can only be accounted for by admitting a different mode of combination.

standing over water and oil, to unknown, but much smaller proportions. It is therefore an object in the analysis of oil and coal gas, to possess means by which their presence and quantity may be ascertained ; and this I find may be done with considerable exactness by the use of sulphuric acid, oil, &c. in consequence of their solvent power over them.

Sulphuric acid is in this respect a very excellent agent. It acts upon all these substances instantly, evolving no sulphurous acid ; and though, when the quantity of substance is considerable as compared with the acid, a body is left undecomposed by, or uncombined with the acid, and volatile, so as constantly to afford a certain portion of vapour ; yet when the original substance is in small quantity, as where it exists in vapour in a given volume of gas, this does not interfere, in consequence of the solubility of the vapour of the new compound produced by the action of the acid in the acid itself in small quantities : and I found that when 1 volume of the vapour of any of the products of the oil gas liquor was acted upon, either alone, or mixed with 1, 2, 3, 4, up to 12 volumes of air, oxygen or hydrogen, by from half a volume to a volume of sulphuric acid, it was entirely absorbed and removed.

When olefiant gas is present, additional care is required in analytical experiments, in consequence of the gradual combination of the olefiant gas with the sulphuric acid. I found that 1 volume of sulphuric acid in abundance of olefiant gas, absorbed about 7 volumes in 24 hours in the dull light of a room ; sun-shine seemed to increase the action a little. When the olefiant gas was diluted with air or hydrogen, the quantity absorbed in a given time was much diminished ; and in those cases it was hardly appreciable in

two hours : a length of time which appears to be quite sufficient for the removal of any of the peculiar vapours from oil or coal gas.

My mode of operating was generally in glass tubes over clean mercury,* introducing the gas, vapour or mixture, and then throwing up the sulphuric acid by means of a bent tube with a bulb blown in it, passing the acid through the mercury by the force of the mouth. The following results are given as illustrations of the process :

Oil gas from a gasometer.

			in 8'	in 1 hour.	2 hours.	diminution.
188 vol.	+	9.5 vol. sulphuric acid diminished to	155	148.5	146.4	22.12 per cent.
107	+	13. - - - - -	88.5	84.5	82.0	23.33
138	+	5.2 - - - - -	113.7	108.0	106.5	22.82

Oil gas from GORDON's lamp.

			15'	30'	3 hours.
214	+	6.8 - - - - -	183.3	180.8	176. 17.75
159	+	5.9 - - - - -	137.5	136.0	130.4 17.98
113	+	12.2 - - - - -	98.0	96.0	92.0 18.58

Coal gas of poor quality.

548.6	+	27.6 - - - - -	533.3	529.2	529	3.57
273.6	+	27.8 - - - - -	267.9	266	266	2.78
190.6	+	13.1 - - - - -	186.	184.2	184.1	3.41

Oil may also be used in a similar manner for the separation of these vapours. It condenses about 6 volumes of the most elastic vapour at common temperatures, and it dissolves with greater facility the vapour of those liquids requiring higher temperatures for their ebullition. I found that in

* If the mercury contain oxidizable metals, the sulphuric acid acts upon it, and evolves sulphurous acid gas. It may be cleaned sufficiently by being left in contact with sulphuric acid for 24 hours, agitating it frequently at intervals.

mixtures made with air or oxygen for detonation, I could readily separate the vapour by means of olive oil ; and when olefiant and other gases were present, its solvent power over them was prevented, by first agitating the oil with olefiant gas or with a portion of the gas to saturate it, and then using it for the removal of the vapours.

In the same way some of the more fixed essential oils may be used, as *dry* oil of turpentine ; and even a portion of the condensed liquor itself, as that part which requires a temperature of 220° or 230° for its ebullition : care being taken to estimate the expansion of the gas by the vapour of the liquid, which may readily be done by a known portion of common *air preserved over* the liquid as a standard.

With reference to the proportions of the different substances in the liquid as obtained by condensation of oil gas, it is extremely difficult to obtain any thing like precise results, in consequence of the immense number of rectifications required to separate the more volatile from the less volatile portions ; but the following table will furnish an approximation. It contains the loss of 100 parts by weight of the original fluid by evaporation in a flask for every 10° in elevation of temperature, the substance being retained in a state of ebullition.

100 parts at 58°	had lost at 70°	parts.	differences.
	-	1.1	- - - 1.9
	80°	- - 3.0	- - - 2.2
	90°	- - 5.2	- - - 2.5
	100°	- - 7.7	- - - 2.4
	110°	- - 10.1	- - - 3.1

120°	-	-	13.2	-	-	2.9
130°	-	-	16.1	-	-	3.2
140°	-	-	19.3	-	-	3.1
150°	-	-	22.4	-	-	3.2
160°	-	-	25.6	-	-	3.4
170°	-	-	29.0	-	-	15.7
180°	-	-	44.7	-	-	23.4
190°	-	-	68.1	-	-	23.4
200°	-	-	84.2	-	-	16.1
210°	-	-	91.6	-	-	7.4
220°	-	-	95.3	-	-	3.7
230°	-	-	96.6	-	-	1.3

The residue 3.4 parts was dissipated before 250° with slight decomposition. The third column expresses the quantity volatilized between each 10° , and indicates the existence of what has been described as bi-carburet of hydrogen in considerable quantity.

The importance of these vapours in oil gas, as contributing to its very high illuminating powers, will be appreciated, when it is considered that with many of them, and those of the denser kind, it is quite saturated. On distilling a portion of liquid, which had condensed in the pipes leading to an oil gas gasometer, and given to me by Mr. HENNEL, of the Apothecaries' Hall, I found it to contain portions of the bi-carburet of hydrogen. It was detected by submitting the small quantity of liquid which distilled over before 190° to a cold of 0° , when the substance crystallized from the solution. It is evident therefore, that the gas from which it was deposited must have been saturated with it. On distilling a portion of recent

coal gas tar, as was expected, none could be detected in it, but the action of sulphuric acid is sufficient to show the existence of some of these bodies in the coal gas itself.

With respect to the probable uses of the fluid from compressed oil gas, it is evident in the first place, that being thus volatile, it will if introduced into gas which burns with a pale flame, give such quantity of vapour as to make it brightly illuminating ; and even the vapour of those portions which require temperatures of 170° 180° or higher for their ebullition, is so dense as to be fully sufficient for this purpose in small quantities. A taper was burnt out in a jar of common air over water ; a portion of fluid boiling at 190° was thrown up into it, and agitated ; the mixture then burnt from a large aperture with the bright flame and appearance of oil gas, though of course many times the quantity that would have been required of oil gas for the same light was consumed : at the same time there was no mixture of blueness with the flame, whether it were large or small. Mr. GORDON has I understand proposed using it in this manner.

The fluid is also an excellent solvent of caoutchouc, surpassing every other substance in this quality. It has already been applied to this purpose.

It will answer all the purposes to which the essential oils are applied as solvents, as in varnishes, &c. and in some cases where volatility is required, when rectified it will far surpass them.

It is possible that, at some future time, when we better understand the minute changes which take place during the decomposition of oil, fat, and other substances by heat, and have more command of the process, that this substance,

among others, may furnish the fuel for a lamp, which remaining a fluid at the pressure of two or three atmospheres, but becoming a vapour at less pressure, shall possess all the advantages of a gas lamp, without involving the necessity of high pressure.

Royal Institution, June 7, 1825.